Breaking the 15 t/ha wheat yield barrier

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Abstract

Recently, a grower in North Otago, New Zealand, applied to be listed in the Guinness Book of Records for producing a 15.048 t/ha wheat yield. This exceeds the world record achieved in Scotland in 1981 by over 1 t/ha. However, such high yields are not possible every year. In this paper we use experimental field data to examine the environmental and management circumstances that colluded to enable the production of a 15 t/ha wheat crop. We conclude that the recipe for a world record includes a combination of cultivar and sowing date that will lead to grain growing through the solar radiation peak, a cool but sunny summer, and attention to agronomic detail so that no growth constraints apply.

Media summary

The odds are with the Kiwis for producing world record wheat crops, with careful management combined with a favourable climate suited to growing high yields.

Key Words

Grain yield, grain fill duration, solar radiation.

Introduction

The official world record yield of 13.99 t/ha for a wheat crop at the field scale was obtained in the United Kingdom (UK) in 1981 by a mixed cultivar crop (Chalmers 2003). Recently, a grower in North Otago, New Zealand (NZ), applied to be listed in the Guinness Book of Records for yields produced by two English feed wheat cultivars that were16.2 t/ha and 14.3 t/ha at 14% grain moisture content from two fields (Chalmers 2003). Such large yields require high populations of large grains. Filling such a large population will require a high grain growth rate sustained for a long time.

Assimilate production from current photosynthesis contributes around 75% of grain yield in a high yielding crop (Jamieson et al. 1998). The remainder is derived from carbohydrate stored in the stems. The amount contributed by each source varies among cultivars and seasons. The production of dry matter is limited by the amount of incoming solar radiation (SR). A high yielding crop would ideally have its grain fill period coinciding with peak SR to maximise production. The duration of grain fill is determined by temperature, with cooler temperatures extending the grain fill period. As well as being shortened by high temperatures, grain fill duration can be reduced by drought, inadequate nitrogen (N) supply, and pests and diseases (Spiertz and Vos 1985). Such limitations may cause the canopy to senesce prematurely, and grain filling then relies more on the reserves stored in the stems (Blum et al. 1994). Low yields with small poorly filled grains and low grain weight are typical of early canopy senescence. Use of N fertiliser (Hocking and Stapper 2001), fungicides (Gooding et al. 2000), pesticides and irrigation (Panozzo and Eagles 1999), plus the right combination of sowing date (Hocking and Stapper 2001), and cultivar can often overcome such limitations by extending the life of the canopy.

Advice for wheat growers in the UK wanting to achieve a 10 t/ha yield is to aim for an ear population of 600 per m^2 with an average 36 grains per ear (Sylvester-Bradley et al. 1997). This gives a grain number of 21,600 grains per m^2. To achieve a 15 t/ha crop in NZ with a similar ear population would require more grains with a heavier weight, say a 50 mg mean grain weight with an average 50 gains/ear, or 30,000 grains/m^2. Growers in the UK should aim for a grain fill period of 49 days from flowering to maximum dry weight (Sylvester-Bradley et al. 1997). To achieve larger grain weights in NZ, a longer grain filling period or a faster rate of filling is needed. This would mean producing at least 300 kg/ha/day for the equivalent grain filling period in the UK. In this paper we examine the circumstances that led to the production of a 15 t/ha wheat yield in one of our experimental crops in the same season.

Methods

An example of a crop yielding over 15 t/ha was taken from a field trial conducted in the Canterbury region of NZ in the 2002-03 season. Savannah, an autumn feed wheat cultivar, was direct-drilled on 6 May 2002 in a stony silt loam soil. Mid-flowering occurred on 1 December 2002. The crop was irrigated six times with approximately 40 mm of water applied each time. Rainfall from sowing to maturity was 505 mm. Two treatments had 207 and 230 kg N/ha applied in three applications, while a third treatment received no N fertiliser. There were three replicates. Soil mineral N was 50 kg N/ha in the top 25 cm shortly after crop emergence. Deeper N measurements could not be taken because the stony soil made sampling impossible.

Daily SR and mean temperature data from a nearby weather station were measured during the grain fill period. Grain fill duration was calculated as the time from anthesis to physiological maturity (PM). For the field trial, PM was taken as the date when the canopy had fully senesced. Ten years of daily data from 1 December to 31 January, were averaged to obtain estimates of daily mean SR and temperature covering the range of grain filling periods occurring in Canterbury.

Results

Yields of the example crop in the 2002-03 season exceeded 15 t/ha when N was applied, and around 11 t/ha when no N was applied (Table 1).

Table 1. Yield and mean grain weight (mg) at 14% grain moisture content, and ears/m^2 harvested from a crop of Savannah wheat in Canterbury, NZ, in 2003.

Treatment (kg N/ha)	Yield (t/ha)	Mean grain weight (mg)	Ears/m2	Grains/ear	Grains/m2
0	11.1	52.9	402	52.2	20980
207	15.1	52.9	491	58.1	28530
230	15.5	53.3	494	58.9	29100
LSD (*P*=0.05)	0.74	2.15	47.7		

Mean grain weight was approximately 53 mg, the ear population was about 490 per m^2, and the grain population was about 29,000 per m^2 when N was added. These are close to the values suggested above, with a slightly heavier grain weight compensating for a slightly lower grain number. In contrast the unfertilised treatment produced only 11 t/ha (still a very good yield) expressed as a lower grain number at the same grain weight. This came about through reductions in the number of ears and grains per ear (Table 1).

Table 2. Grain fill duration and accumulated mean daily solar radiation (MJ/m^2) and temperature (?C) values for a crop of Savannah wheat grown in Canterbury, NZ, in the 2002-03 season.

Anthesis date	Maturity date	Grain fill duration (days)	Mean daily solar radiation (MJ/m^2)	Mean daily temperature (?C)
1-Dec-02	10-Jan-03	40	26.2	16.5

The grain fill period for the example crop was approximately 40 days (Table 2). Assuming 25% of the final yield came from storage in the crop, the remaining 11.3 t/ha (or 9.8 t/ha dry matter) would have been produced from current photosynthesis. The mean daily SR was 26.2 MJ/m^2, which would produce around 290 kg/ha dry matter a day assuming a radiation use efficiency of 1.1 g/MJ (Jamieson et al. 1998), or 11,600 kg/ha over the 40-day period. This rate of production probably declined as the canopy senesced. The value here exceeds the yield, and this would compensate for the drop in production rate towards maturity.

This illustrates the potential for producing biomass in NZ's climate. However, mean daily SR was higher than usual in the 2002-03 season. The average for the last 10 years during the grain filling period was only 23 MJ/m^2 (Figure 1). This would produce 250 kg/ha dry matter a day, 40 kg/ha a day less than the crop that produced 15 t/ha. Under average SR conditions, temperatures would need to be cooler to extend grain filling to compensate for the reduced growth rate. Mean temperature during grain filling for this example (Table 2) was a little warmer than the 10-year mean of 15.7?C for this period. Interestingly, if our coolest mean temperature of 14.5?C coincided with the high SR in Table 2, the combination could theoretically lead to a grain yield of 18.9 t/ha at 14% moisture content.

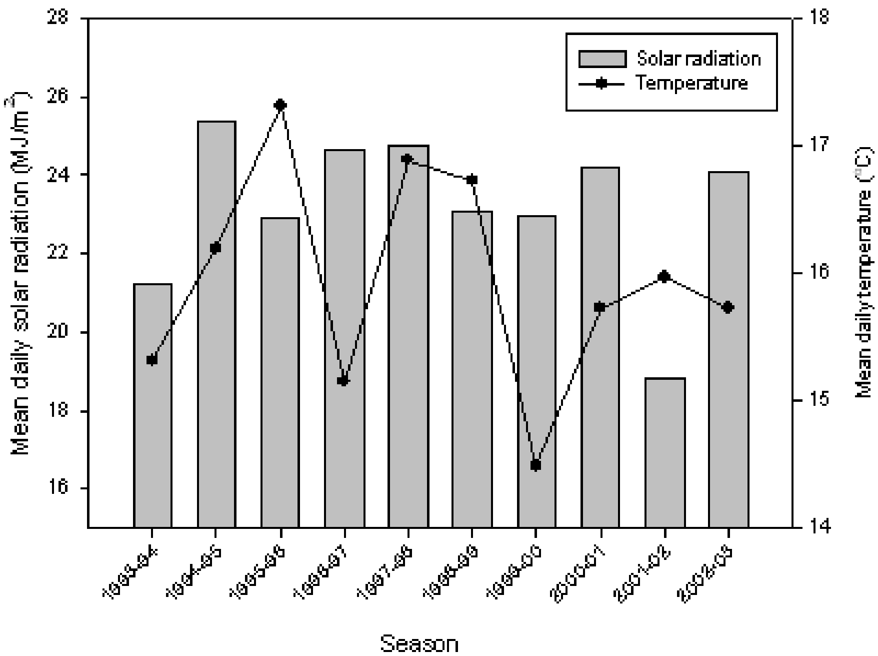

Figure 1. Mean daily solar radiation (MJ/m^2) and temperature (?C) for the grain fill period 1 December to 31 January, across 10 seasons in Canterbury, NZ.

Cool temperatures combined with high SR do not occur often during grain fill. For example, grain yields in Canterbury were generally lower than usual in 2001-02 because the season was unusually cloudy and SR during the grain-filling period was well below average (Figure 1). The example crop was able to maximise its growth rate because the grain fill period coincided with the peak of SR (Figure 2). The timing of crop developmental stages depends on the combination of cultivar and the time of sowing. Regular applications of N and irrigation ensured the survival of the canopy through the period of peak radiation.

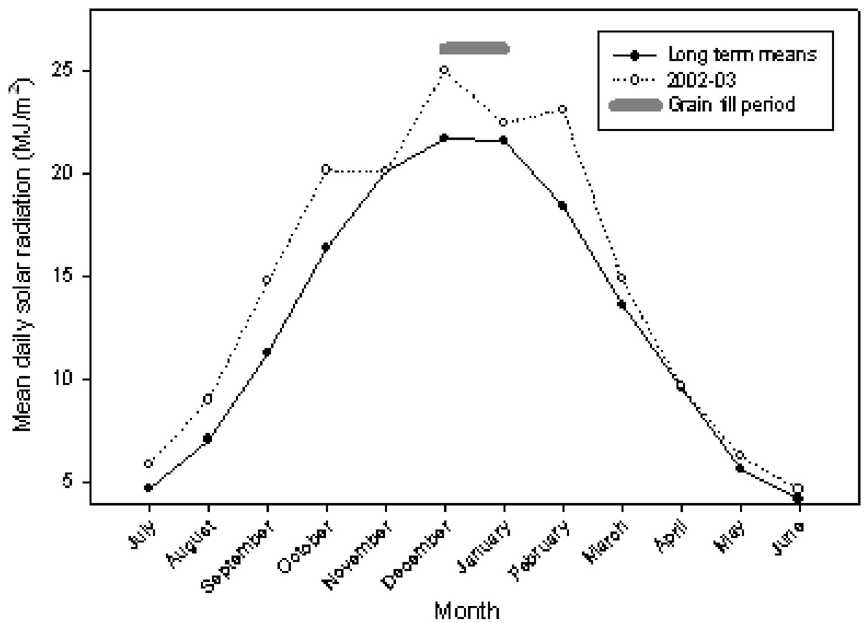

Figure 2. Mean daily solar radiation (MJ/m^2) for each month across 10 seasons, and for the 2002-03 season in Canterbury, NZ.

Conclusion

An exceptional combination of events combined to enable a yield exceeding 15 t/ha. Good management, near average temperatures and above average solar radiation occurred during the grain filling period of the crop. Variations in temperature and solar radiation during the grain filling months mean we cannot expect yields exceeding 15 t/ha every year. However, setting up the crop so that it can take advantage of such optimum conditions will ensure high yields when they occur.

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